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In-Flame Measurements on Full-Scale Swirl Stabilized Bio-Dust Burners at Different Operational Conditions

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Oral presentation at the symposium is preferred

1. Summary and Purpose

A series of full-scale flame mapping campaigns on swirl stabilized bio-dust burners have been conducted at two different combined heat and power (CHP) plants in Denmark: Amagerværket Unit 1 (AMV1, 350 MW_{th}) and Herningværket (HEV, 300 MW_{th}) owned and operated by Vattenfall and DONG Energy Power, respectively. The two burners, both being in the 30-40 MW_{th} size, represents two different generations of low NO_x air-staged, swirl-stabilized wall burners for bio-dust combustion. The work provide quantified in-flame data of gas temperature, O₂, CO, CO₂, H₂O, and light hydrocarbons from full-scale flames. The obtained measuring data will together with CFD modeling support the development of the next generation of bio-dust fired burners. The issue of scaling is well known in the academic literature and thus, full-scale results constitute an important step towards an understanding of burner dynamics and model evaluations.

2. Approach and Methods, Scientific Innovation, and Relevance

Systematic, large amplitude variations in burner operational conditions have been applied and the corresponding changes in flame behavior have been measured. The variations in operational conditions include the following parameters: Air flows (primary (PA), secondary (SA), tertiary (TA), and combinations hereof), temperature, swirl, and fuel particle sizes. The flame response has been evaluated using both non-intrusive optical measurements and probe measurements; and corresponding samples of fuel pellets and pulverized fuel were collected. These measurements included: Temperature measurements using both suction pyrometry and optical fourier transform infrared (FTIR) spectroscopy. Gas species concentrations have been quantified by extraction of gas samples analysed by parallel infrared (IR) and ultraviolet (UV) cells and O₂ paramagnetic analyser. Flame shapes and particle cloud behavior have been observed using high speed imaging in both the visual and IR region. Specialized equipment has been developed specifically for these campaigns and includes among other a 5 m single part and a two part 8.6 m water cooled probe capable of reaching far into the boiler through the centre of the burner. Optical observations were applied both in the visual and the infrared region for flame behaviour evaluation, particle cloud trajectories, and particle cloud surface measurements by two-line pyrometry.

3. Results

Pyrolysis and combustion fronts can be identified by characteristic peaks in the pyrolysis gas concentrations (appearing between 0.75 and >2 m from the burner) and axial shifts in the temperature profile (maximal temperature increase takes place between 0.5 and 1.5 m from the burner), respectively. Changes in the air flow dynamics was found to influence to the greatest extend on these properties. Increasing the local O₂ excess through an increase in the SA flow pulls the pyrolysis front closer to the burner mouth with no apparent change in gas phase temperature. The opposite effect can be found when increasing the TA flow relative to the SA flow while maintaining the overall stoichiometry. This destabilizes the internal recirculation zone (IRZ) and both pyrolysis and combustion is found to take place further down-stream of the burner mouth. In general flow characteristics influencing the IRZ seem to have high impact on the measured parameters. Decreasing the swirl number by approximately 20 % reduces (>50 %) or in some cases even eliminates the presence of pyrolysis gases from maximum quantities of 2-3 vol. % of CO and 2-3 vol. % of CH₄ and C₂H₂ under normal operational conditions. Destabilizing the IRZ also lowers the flame temperature in the near burner field with as much as 200 K in a flame temperatures spanning between 1000-1750 K depending on the specific sample point.

Flame stability was evaluated assisted by optical observations: charge-coupled device and IR imaging. Flame lift could clearly be seen in the visual spectra and flame stabilization up to 1 m from the burner mouth was frequently observed in longer periods: up to 30 % of the time in some cases. Such flame instability was not immediately obvious from the temperature or chemical species profiles but could be correlated to the entrainment of cold particles into the furnace, identified using two-line pyrometry in the IR region. Significant penetration of cold particles (<850 K) could be observed under certain conditions entraining cold particles as far as 2 m into the furnace.

4. Conclusions

Coarse flame mapping along the centre line of a wall fired, swirl stabilized pulverized flame has proven successful for quantitative observations of flame responses to changes in burner operating conditions. The observed flame responses were all significant and a good all-round understanding of the burner dynamics of the two investigated burners can be derived. The reproducibility, e.g. in reference runs, were found to be good and thus, this work constitute a complete set of measurement data that can be used for large-scale model evaluation.

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